Features of the physical and chemical characteristics of water of energy facilities for aquaculture tasks

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Abstract. Energy facilities and water are inextricably linked. Accordingly, the issue of water quality, its transformation as a result of industrial use of energy facilities and the assessment of further use for aquaculture purposes is an urgent task of our time, especially in relation to weather and climate risks for industries. The article provides a classification of water according to the water supply technology of energy facilities by temperature factor and the possibility of using it for aquaculture tasks. In total, three classes of water are distinguished according to the temperature factor: waters with natural physical and chemical characteristics, where the temperature regime of reservoirs corresponds to the geographical zone in which the reservoir is located (cultivation of fish associated with fish-breeding zone in which the reservoir is located); water of bassin-coolers of energy facilities, characterized by the presence of a zone of increased temperatures as a result of the discharge of heated water (organization of flood-proof farms with polycyclic production); water of cooling ponds (cultivating fish capable to the fight against eutrophication).

1 Introduction

Water ecosystems are a source of water for humans and industry, so they are multi-purpose objects of using. This article investigates water ecosystems as an integral component of energy facilities. The World Energy Council estimated the amount of water consumption for energy production at 583 billion m3, which is about 15% of the total water consumption in the world. The volume of irretrievably used water amounted to 66 billion m3. This problem (water consumption and as a result water quality) is one of the priorities to date and is being discussed in the world scientific community, especially in China [1-3]. According to the International Energy Agency's global energy scenario, water intake increased by about 20% between 2010 and 2015, and water use (including re-use) increased to 85%. All this leads to the need to understand the possibilities and ways of sharing water for industrial needs and for household (food). This issue is particularly relevant in the context of ongoing climate change.

To date, the economic damage from climate change is estimated at $1.2 trillion per year (in 2012 prices), or 1.6% of global GDP [4-7]. In Russia, because of its northern location, the climate is warmer faster than in the rest of the world. According to Yu. A. Izrael institute of global climate and ecology of federal service for hydrometeorology and environmental monitoring and Russian academy of sciences, the growth rate of average annual temperature in Russia is 2.5 times higher than the global average, and in the Northern Polar Region - 4 times.

The report on climate risks in the territory of Russian Federation (2017) provides estimates of the impact of climate and meteorological factors on life and health, the state of infrastructure facilities, agriculture and forestry, which indicate that agriculture (30%) are more at risk in the Volga Federal District, than energy and social sector (20%). Fisheries, transport and the mining industry (10%) are closing the chain of risk in the Volga Federal District [8].

This raises questions about the possibility of using natural waters involved in the operation of energy facilities for aquaculture tasks. It is necessary to understand that in aquaculture the main indicator for the selection of the fish breeding is the temperature factor. In addition, for the successful reproduction and fish breeding it is necessary to organize the continued monitoring of such physicochemical characteristics as dissolved oxygen concentration, pH. Numerous researches conducted at the Department of Water bioresources and aquaculture of Kazan State Power Engineering University allow us to propose redox potential and total antioxidant activity as promising physicochemical indicators.

2 Materials and methods

Data collection on physical and chemical characteristics of water in natural reservoirs, including the reservoirs of energy facilities, of the Republic of Tatarstan was carried out from 2010 to the present time.

The redox potential (Eh) and pH were measured by the ionomer I-160 MI. According to the certificate of this device, Eh is measured by combined electrode and a

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comparison electrode. The combined electrode has a glass body with a diameter of 12 mm. In its lower part of device there is a working membrane sensitive to hydrogen ions, which is a ball made of special glass. Porous ceramic is soldered above the ball, providing electrolytic contact between the electrolyte poured into the electrode and the analysed solution. The upper part of the electrode ends with a sleeve, from which a cable comes out with a connector for connection to the converter.

Total antioxidant activity (TAOA) was determined by culonometric method using electrogenerated bromine. Samples were analyzed on the Expert-006 coulometer (Ekonix-Expert LLC, Russia) using a certified methodology. Electricity generation of bromine was carried out from a 0.2 M solution of potassium bromide in a 0.1 M aqueous solution of sulfuric acid at a constant current strength of 100.0 mA. 30 ml of the background solution was introduced into the electrolytic cell and when the test current reached a certain value, an aliquot of the aqueous extract of the test sample of 100 mkl. The determination was carried out at room temperature. The device was calibrated with an alcoholic solution of the Russian standard sample (RSS) of the routine prepared according to the current State Pharmacopoeia of the XI edition. TAOA was expressed in mg of a standard rutin (Ru) sample per 1 dm^3 of extraction or in g of Ru per 100 g of test sample.

Statistical processing of obtained results was carried out through modal value (mode) of 10 definitions, relative error of determination of TAOA of tested samples (E relative) was within 3.0-5.0%.

The dissolved oxygen concentration and water temperature were determined by oximeter «Mark 302E».

All collected data were statistically processed using Microsoft Excel and Statgraphics Plus 5.1.

3 Results and discussions

The change in the temperature regime of the regions leads to a change in the objects of cultivation [9-11], therefore, it is necessary to understand to which fish-breeding zone reservoir belongs where the object of energy is located and is planned for aquaculture purposes.

For example, in 1986, the Tatar ASSR was classified to two fish-breeding zone with a number of days per year with an air temperature of more than 15°C from 76 to 90. Currently, according to the calculations, the Republic of Tatarstan can be attributed to 5 fish-breeding zone (121-135 degree-days) (Fig. 1) [12]. Thus, in about 30 years there has been changed to 3 positions.

An additional increase the water temperature occurs due to the discharge of heated water of thermal power plants, which also leads to changes in the choice of both the breeding object and the conditions of cultivation.

However, the work of not all energy facilities leads to a change in the temperature of the aquatic ecosystem, which is a source of water. Accordingly, it is necessary to classify the waters used for energy purposes by temperature factor.

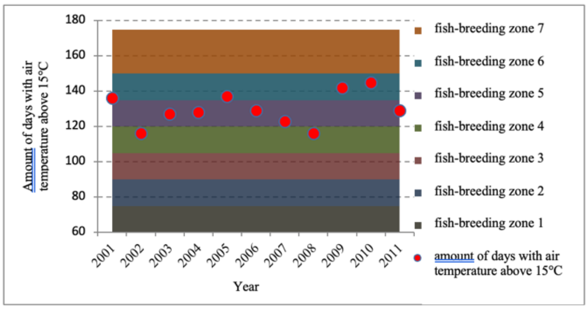

Fig. 1. Number of days per year with an air temperature above 15°C in the last 11 years in the Kazan city.

Suppose that the 1st class is the water with natural physical and chemical characteristics, that is the temperature condition of the reservoir in this case will correspond to the geographical area in which the reservoir is located. An example of possible energy facilities: hydroelectric power plants. In this case, the choice of aquaculture object will be determined by the fish-breeding zone in which the reservoir is located. For example, in the Republic of Tatarstan it is the Nizhnekamsk hydroelectric power plant, located on the Kama River. The temperature condition of water mass has a stable annual cyclicality. The average water temperature in the summer time is 23°C. From 2018 to 2020, more than 100 rivers of the Republic of Tatarstan were investigated to analyze the dynamics of the redox potential of water. It was found that the range of change of Eh is from -21.1 mV to -166.1 mV. The average value of the Eh in the Kama River is -86.3±2.5 mV in the summer. In a comparative aspect, the value of the redox potential of the Kama River with other large rivers of the Republic of Tatarstan is shown in Fig. 2 [13].

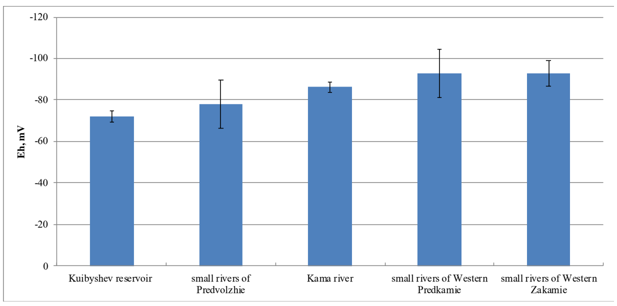

Fig. 2. Dynamics of redox potential in the large rivers of the Republic of Tatarstan [13].

Knowing the Eh values of water, it is necessary to understand the suitability of the obtained values for aquaculture purposes. In this regard, a series of experiments on carp fish species were carried out. It was revealed that for carp fish, the oppression zone lies in the ranges from -176 to -282 mV and from -2 to 80 mV; zone of normal existence from -2 to -176 mV; the zone of optimal values is included in the zone of normal existence and corresponds to the values of Eh in the range from -59 to -149 mV. Thus, the Eh values of the Kama River are located in the zone of optimal existence for carp fish species, which makes this reservoir attractive for aquaculture tasks.

Another promising physical and chemical indicator is total antioxidant activity [14]. The research carried out at the Department of Water Bioresources and Aquaculture of Kazan state power engineering university allowed to identify 9 clusters of TAOA with different chemical characteristics:

Cluster №1 – 7.5469 mg Ru per 1 dm^3;
Cluster №2 – 6.8212 mg Ru per 1 dm^3;
Cluster №3 – 6.0956 mg Ru per 1 dm^3;
Cluster №4 – 5.3699 mg Ru per 1 dm^3;
Cluster №5 – 4.6443 mg Ru per 1 dm^3;
Cluster №6 – 3.9912 mg Ru per 1 dm^3;
Cluster №7 – 3.2655 mg Ru per 1 dm^3;
Cluster №8 – 2.4673 mg Ru per 1 dm^3;
Cluster №9 – 1.8142 mg Ru per 1 dm^3.

Since the structure of natural waters differed in the different percentage of clusters, which were characterized by different values of the TAOA of water, a water structure index is proposed (Fig. 3):

$$Iws = (F \times TAOA) \times Ct/A \quad (1)$$

where, F – Frequency of occurrence of water cluster (in shares);

TAOA – the value of total antioxidant activity (mg Ru per 1 dm^3);

Ct – coefficient of trophy (0.5 – dystrophic reservoirs; 1 – oligotrophic reservoirs; 2 – mesotrophic reservoirs; 3 – eutrophic reservoirs);

A – number of selected clusters in the sample.

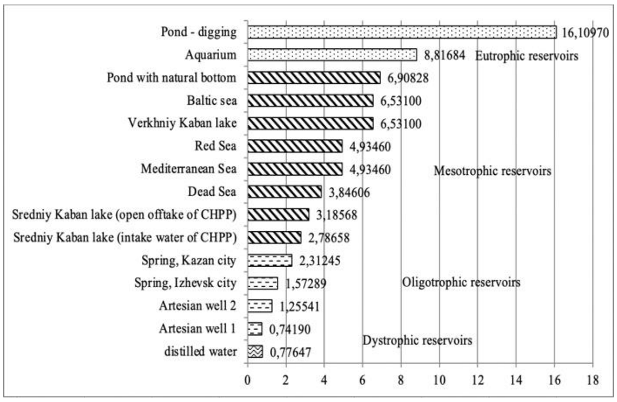

Fig. 3. Water classification according to the Index of water structure.

In general, the Kama River can be described as mesotrophic in the level of trophies. According to this index of the water structure, the water in the Kama River will approach the values of 5-7.

Class 2 is the water of bassin-coolers of energy facilities, characterized by the presence of a zone of increased temperatures as a result of the discharge of heated water. An example of possible energy facilities: state district power plants (GRES) or thermal power plants (CHP) with a direct-flow water supply system. As a result of artificial impact on the ecosystem of the reservoir in the temperature annual mode the disappearance of the winter stagnation period, the extension of the thermocline period (2 months: July, August) is characteristic. The discharge of heated waters does not allow the average temperature to drop below 4°C in winter time. It is in the winter we can see the maximum difference in temperature values relative to the temperature background is observed (up to 11°C) [12, 15]. In general, the thermal condition of these reservoirs can be characterized as unstable and dependent on the operation of energy facilities [16], with an increase in the water temperature in the summer period up to 3°C relative to the temperature background and in the winter period up to 11°C. Redox potential values range from -70 mV [17]. This value indicates a supportive environment for the hydrobionts breeding similar to the 1 class. The water structure index ranges from 2.7 to 3.2. Low index values can be characterized by the use of artesian or spring waters, as it observed at the Zainskaya GRES (mixed source water: the Kama River and the artesian well) and the Kazan CHP-1 (spring makeup of the Lake Sredniy Kaban [12, 18]). A suitable form of fish farming under such conditions is preferably flood-proof houses. Based on the described physicochemical characteristics, these reservoirs are characterized by the cultivation in summer period the fish which less demanding to environmental conditions and possibly having specialized organs for breathing with atmospheric air. It is generally accepted that carp is a less demanding object of aquaculture for environmental conditions. However, in 2016, as a result of abnormally hot summers, 100% of fish deaths in flood-proof farms were recorded at the Zainsky reservoir (for one night, mortality was 170 tons of carp).

In this regard, it is advisable to consider as an aquaculture object for a given class of reservoirs of clarium catfish, which has an above-gill organ, due to which it is capable of breathing atmospheric air. High planting densities of fish grown in flood-proof houses and intensive feeding on them with artificial feed increase the number of organic substances, discharge of heated waters leads to an increase in the average temperature in the reservoir, all this contributes to accelerated eutrophication of the reservoir. With an increase in the trophy of the reservoir, the water structure index will grow and reach 7-8, while the number of TAOA clusters found in the water will decrease (Fig. 3 and 4).

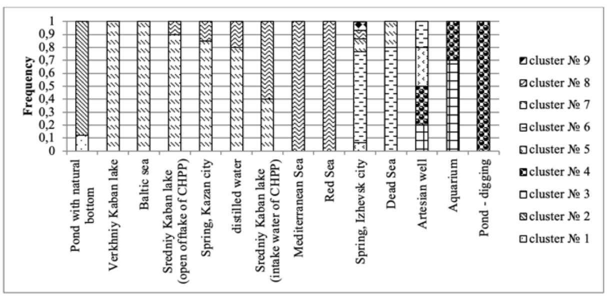

Fig. 4. Water clusters of various water bodies according to the total antioxidant activity.

As we can see on the Figure 4 the simplified (one cluster of water) water structure is possessed by the waters of fish ponds with spring feeding, lakes with weak anthropogenic effects, while the mode of TAOA is the maximum of the researched.

In winter, it is advisable to organize flood-proof of a trout houses: the water temperature is suitable, the concentration of oxygen due to the lack of ice cover and the circulation of water during the passage of the discharge channel reaches the desired values (up to 10 mg/dm^3). Thus, this class of water allows you to organize polycyclic production: in winter, the cultivation of salmon with an optimal temperature of 12-15°C, and in summer – heat-loving fish species with a temperature optimum of 26-30°C, for example, clarium catfish.

Class 3 is the water of cooling ponds. An example of possible energy facilities: thermal power plants operating on a recycled type of technical water supply, nuclear power plants (NPP) [19-21]. This type of water supply occurs in the absence of a reservoir of the necessary capacity, in which case water is pumped to cool the mechanisms and then returned to the artificial cooler. Cooling towers and cooling ponds can act as cooler. Artificial pools are used to remove small amounts of heat, up to about 200.000 kcal/hour, which requires an area of 800-1000 m^2. The artificial pond can be created in 2 ways, in the first case the design feature is the waterproof of the walls and the bottom, it is made in the form of round or rectangular open reinforced concrete tanks located in the recess. Under these conditions, aquaculture tasks are difficult to achieve due to watertight walls, as a result of which constant circulation and replenishment with fresh water is required to avoid acidification of water by accumulating high concentrations of organic compounds (both fodder residues and life products). In this case, in a short period of time, the redox potential values will reach positive values, while in 1 and 2 of the water class described, the Redox potential values were -70-80 mV. As we said earlier, positive values of the redox potential indicate a fall into the zone of oppression and death for carp fish. Nowadays, such artificial basins are increasingly used to cool water due to their high cost and preference is given to the creation of artificial ponds by fencing the river bed with platinum. Such ponds-reservoirs on rivers combine the functions of a cooler and a drain regulator. The depth ranges from 1,5 to 3 meters. These artificial reservoirs are also subject to eutrophication processes and the Redox-potential values will reach -120-160 mV, while the water structure index can reach maximum values (from 9 to 16), and the number of TAOA clusters is minimal (most often 1, Fig. 4). Eutrophication processes can be controlled by the correct selection of hydrobionts for aquaculture purposes.

3 Conclusion

Despite the difference in the temperature regime of the described classes of water and other physicochemical indicators, with the correct selection of biotechnologies, any water can be used. The most suitable water class for aquaculture purposes can be considered 2 - these are the waters of the basin-coolers of energy facilities, characterized by the presence of an elevated temperature zone as a result of the discharge of heated waters. In this case, it is possible to organize polycyclic production and expansion of aquaculture objects, affecting both heat-loving (in the summer) and cold-loving (in the winter) fish species. At the same time, the values of the main physicochemical parameters, such as the concentration of dissolved oxygen (in the summer), Redox-potential, the associated indicator pH are identical to the values in natural reservoirs without thermal influence, and in the winter period the concentration of dissolved oxygen is higher compared to reservoirs without thermal effect.

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